

DEVICE FOR THE 3D FREE-FORM BENDING OF PROFILES

The invention pertains to a device for the 3D free-form bending of profiles with constant outside dimensions over their length, particularly with a circular shape, wherein said device comprises a feed unit that contains a rotary drive for turning the profile about its longitudinal axis and serves for moving the profile with a longitudinal axis in a feed direction that extends parallel to this longitudinal axis, namely through a guide element with a through-opening that adjoins the surface of the profile and a bending sleeve that at least partially encloses the profile to be bent and is arranged downstream of the guide element referred to the feed direction, wherein said bending sleeve is held in a carrier element and can be pivoted about an axis that extends perpendicular to the feed direction of the profile, as well as displaced perpendicular to the longitudinal axis and the pivoting axis, together with said carrier element such that the bending sleeve acts upon the profile in a bending fashion.

3D free-form bending devices are known from the state of the art. For example, JP 08 257 643 A discloses a 3D profile bending device, in which a profile is moved through a stationary guide element and a bending sleeve that is arranged downstream of the guide element referred to the feed direction and integrated into a carrier element. The carrier element is held in a receptacle frame such that it can be turned about a first axis that extends through the center of the bending sleeve perpendicular to the longitudinal axis of the profile to be bent. The receptacle frame itself is supported such that it can be turned about a second axis of rotation that extends through the center of the bending sleeve, namely

perpendicular to the profile axis as well as perpendicular to the first axis. In addition, the receptacle frame can be displaced along both axes. The profile can be bent three-dimensionally by respectively adapting the rotational movement and the displacement of the receptacle frame relative to the rotational movement of the carrier element in the receptacle frame accordingly.

The disadvantage of this bending device is that the different rotational and translational movements of the carrier element and the receptacle frame need to be exactly adapted to one another in order to bend the profile into the desired shape. This not only requires high investment costs, but also a complicated CNC control of the bending device.

EP 0 928 646 A1 discloses another bending device that operates in accordance with the same principle as the above-described device. In addition to the rotational movement about and the translational movement along the respective axes that extend perpendicular to the profile axis and lie orthogonal to one another, the carrier element of this device can also be turned about the longitudinal axis of the profile in order to achieve the desired torsion of the profile during the bending process. Although all degrees of freedom of the bending process are realized with this device, a total of five rotary and linear drives is required in addition to the feed unit, wherein said drives also need to be correspondingly adapted to one another. This means that the drives need to fulfill very high requirements with respect to precision and synchronism, and that this bending device cannot be realized in a cost-efficient fashion.

EP 0 928 645 A1 discloses a simplified variation of a bending device for the 3D free-form bending of profiles. Analogous to the above-described state of the art, the feed unit of this device moves the profile through a non-rotatable guide element and a U-shaped, open bending sleeve arranged downstream thereof. The guide element is inserted into a sleeve that is non-rotatably connected to the machine frame and on which an outer sleeve is rotatably supported. In this case, the axis of rotation of the outer sleeve coincides with the longitudinal axis of the profile. The outer sleeve contains a boom that extends in the feed direction and on the end of which a support element carrying the bending sleeve is arranged such that it can be turned about an axis that extends perpendicular to the feed direction and is laterally offset relative thereto. The position of this axis relative to the bending sleeve is chosen such that the rotational and translational movements of the bending sleeve required for adjusting the desired bending radius can be achieved by means of a single pivoting movement. The three-dimensional bending of the profile is realized by turning the outer sleeve and the open bending sleeve connected thereto about the profile axis by means of the support element and the boom, namely by a certain angle that corresponds to the desired change in the position of the bending plane. Subsequently, the desired bending radius is adjusted once again by turning the bending sleeve accordingly, and the bending process is continued in a new bending plane.

In comparison with the other bending devices described above, this device has a much simpler design that only requires two drives in addition to the feed unit. However, one disadvantage can be seen in the complicated mechanism for turning the bending sleeve by means of the rotatably

supported outer sleeve. This makes it impossible to realize this device in a compact fashion. In addition, a frequently undesirable and extensive straight transition section is frequently formed during the phase, in which the device is adjusted from one bending plane to another bending plane. This device is only suitable for profiles that have a circular cross section, namely because the profile needs to be held in the bending sleeve such that it can be axially turned.

Another 3D bending device for bending profiles with a circular cross-sectional shape is known from practical applications, wherein the profile is moved through a non-rotatable guide sleeve that encloses the profile with a positive fit, as well as through a bending sleeve arranged downstream thereof, wherein said bending sleeve is held in a carrier element and also encloses the profile with a positive fit. The rotational and translational movements of the bending sleeve required for adjusting the desired bending radius can be realized due to the fact that the bending sleeve is held in a rocker by the carrier element such that it can be turned perpendicular to the feed direction. In this case, an actuating cylinder is used for turning the bending sleeve by means of a boom. In contrast to the previously described state of the art, the bending plane is not changed by turning the bending sleeve about the longitudinal axis of the profile in this case, but rather by turning the bending sleeve about its longitudinal axis with the aid of a drive integrated into the feed unit. This results in the relative movement between the bending sleeve and the profile to be bent taking place in an unchanged fashion.

These measures make it possible to achieve a more compact design of the bending device than in the previously cited state of the art. Nevertheless, this device is also unsuitable for bending profiles with non-circular cross sections because it must be possible to turn the profile in the guide sleeve as well as in the bending sleeve.

The relevant state of the art also discloses drawing/bending machines for hollow profiles that have become quite popular in the automobile industry. However, these machines are only able to bend profiles in one plane, i.e., 2-dimensionally. A drawing/bending machine for thin-walled metal pipes is described in DE 100 20 727 C1. In this case, the front end of the pipe is clamped in position in a fastening device by means of clamping jaws. When processing thin-walled pipes, the inside of the pipe needs to be supported by a grip head in the clamping region and by a bending block in the bending region. Once the pipe is fastened in the desired position, the bending process is initiated by turning a bending table with a circular shape that defines the attainable bending radius about its axis of rotation. This causes the pipe to be drawn forward and to be simultaneously bent by the bending table. In addition to being limited to bending processes in only one plane, the fundamental disadvantage of such drawing/bending machines can be seen in the fact that no variable radii and no bending about the longitudinal axis of the profile can be realized.

The invention is based on the objective of developing a device that has a simple design and allows the 3D free-form bending of profiles with a constant outside contour over their length, for example, a circular contour, an oval contour or the contour of a regular polygon, etc.

According to the invention, this objective is attained with a device of the initially described type in that

- a) the profile is supported such that it can be turned about the longitudinal axis in or with the guide element,
- b) the profile is supported such that it can be turned about the longitudinal axis in or with the bending sleeve,
- c) the bending sleeve is supported such that it can be eccentrically pivoted about a first hinge point of a rocker by means of the carrier element, wherein the rocker, in turn, is supported such that it can be pivoted about a second hinge point that is arranged eccentric to the longitudinal axis of the profile on the same side of the profile as the first hinge point, and
- d) the carrier element is held in a guide groove on the opposite side of the profile referred to the hinge points, namely such that the inner surface region of the bending sleeve that acts upon the outside of the profile in a bending fashion is, discounting the resilience of the profile, always aligned tangential referred to a circular arc that corresponds to the respectively desired bending radius when the position of the carrier element part supported in the guide groove is changed.

The 3D free-form bending of a profile with constant outside dimensions over its length is achieved in that the profile can be turned about its longitudinal axis relative to the stationary position of the bending sleeve by means of the rotary drive acting upon the profile. When bending

profiles with a non-circular cross section, the guide element is also axially turned in its receptacle unit and the bending sleeve is axially turned in the carrier element, particularly due to a positive fit. However, when processing profiles with a circular cross section, the guide sleeve and the bending sleeve may also be rigidly connected to their respective receptacles. Since the profile is turned, the bending plane also remains unchanged after a change in the bending direction. The device may have a comparatively simple design since it can be realized in the form of an add-on unit for a 2D drawing/bending machine. The movement of the bending sleeve for adjusting the bending radius takes place in one plane and can be coupled, for example, with the movement of the bending table of a drawing/bending machine. Consequently, important components of a conventional drawing/bending machine can still be utilized. Facilities that are already equipped with drawing/bending machines for 2D-bending processes can be converted into 3D profile bending facilities without having to invest in completely new machines. The positioning drive for the bending sleeve can be inexpensively realized with a minimal number of movable parts due to the eccentrically pivoted support of the carrier element with the bending sleeve about the hinge point of a rocker. In this case, the installation and control of linear drives for displacing the carrier element in two directions in space can be completely eliminated.

A compact design of the device according to the invention can be achieved if the guide element is realized in the form of a guide sleeve that can be turned about the longitudinal axis of the profile. In this case, it is particularly advantageous to longitudinally divide the

guide sleeve. If the guide sleeve is divided, for example, into two halves, the clearance between the profile and the guide sleeve and consequently between the profile and the bending sleeve can be completely eliminated. In comparison with the state of the art, this makes it possible to bend profiles with a particularly small bending radius.

The profile cross section can also be altered in a targeted fashion before the bending process if the through-opening of the guide element has a cross-sectional shape that essentially changes continuously in the feed direction, namely such that the guide element acts upon the profile as the shaping tool. The guide element may be provided, for example, with shaped elements that are inserted into its through-opening for this purpose. Slight changes in the cross-sectional shape can be achieved in the cold state. If more significant changes in the cross-sectional shape are required, it is practical to provide the guide element with a heater for heating the profile. It goes without saying that the heating device also promotes the bending of profiles with a small bending radius if the cross-sectional shape is constant.

According to one advantageous embodiment of the invention, the edges of the through-opening of the guide sleeve are rounded on the inlet side and/or the outlet side. This simplifies the insertion of the profile into the bending sleeve during the preparation of the bending process.

The device according to the invention also is particularly suitable for bending hollow profiles with variable bending radii. When bending profiles with small bending radii, the device contains a bending block that supports the inside of the hollow profile during the bending process. This

effectively prevents the hollow profile from collapsing, in particular, when bending the profile with small bending radii, and the formation of wrinkles in the bent region is reduced.

One prerequisite for obtaining a uniform bending result in accordance with the adjusted bending radius while simultaneously minimizing the tensions occurring in the profile to be bent is the tangential alignment of the inner surface region of the bending sleeve that acts upon the outside of the profile in a bending fashion relative to a circular arc that corresponds to the bending radius. Depending on the cross-sectional geometry and the wall thickness of the profile relative to the enclosed cross-sectional surface, the bending does not begin at the outlet of the guide element, but rather in the guide element if no bending block is utilized as an internal support for the profile to be bent. This causes a displacement of the circular arc opposite to the feed direction. In this case, the continued tangential alignment of the bending sleeve relative to the displaced circular arc is achieved by realizing the progression of the guide groove such that it can be adjusted relative to the longitudinal axis of the profile.

In addition to the bending process, a plastic torsion of the profile about its longitudinal axis can be realized by providing the bending sleeve with a rotary drive. In this case, the bending sleeve and the profile to be bent are collectively turned about the longitudinal axis of the profile by means of the rotary drive while a corresponding rotation of the guide sleeve is prevented by means of a suitable blocking mechanism. For example, the rotary drive may be integrated into the carrier element.

The bending sleeve may be designed differently with respect to the adaptation of the sleeve opening to the cross section of the respective profile to be bent. For example, the bending sleeve may completely enclose the profile. A particularly variable utilization can also be achieved with a U-shaped bending sleeve.

Analogous to the guide sleeve, the insertion of the profile into the bending sleeve can be simplified by rounding the edges of the bending sleeve on the inlet side and/or the outlet side. During the insertion of the profile and during the operation of the device, the bending sleeve needs to be adequately secured against the axial thrust exerted by the profile. The fact that the inner surface of the bending sleeve contains, referred to the feed direction, a linear region or a region with a slight concave curvature also assists in achieving a bending result that exactly corresponds to the respective specifications. If the profile to be bent consists of a hollow profile with a circular outer contour, this region should amount to $= 1/5$ of the profile diameter.

In order to additionally minimize the formation of wrinkles during the bending process, it is practical to arrange a shaped element with an adapted through-opening that sectionally corresponds to the cross section of the profile between the guide element and the bending sleeve, particularly coaxial to the guide element such that it acts upon the profile as a device for smoothing out wrinkles. When bending hollow profiles, this element is used as a supplement to the previously described bending block such that the bending radius can be additionally reduced. Depending on the respective application, this

element may be rigid or flexible. When bending a profile with a circular outer contour, it is sensible to realize this element with an annular shape. According to one particularly advantageous embodiment of the invention, this element is realized in the form of an extension of the guide element in the direction of the bending sleeve. It would also be conceivable to realize this element in the form of an extension of the bending sleeve in the direction of the guide element. In both instances, it is practical to realize the shaped element in a U-shaped fashion such that the lateral flanks of the profile are supported during the bending process. A flexible variation of the shaped element may be realized in the form of a coil spring or manufactured from an elastic rubber material, for example, a synthetic elastomer.

The invention is described in greater detail below with reference to the embodiment illustrated in the figures. The individual figures show:

Figure 1, a side view of a device for the 3D free-form bending of profiles with a hollow profile inserted therein immediately before the bending process begins;

Figure 2, a longitudinal section through the device according to Figure 1;

Figure 3, a perspective representation of the device according to Figure 1, and

Figure 4, a detailed cross section through the device according to Figure 1 along the line I-I in Figure 2.

The bending device contains a guide element 1 in the form of a guide sleeve that is supported in a stationary receptacle block 2 by means of two bearings 2a, namely such that it can be turned about its longitudinal axis L. This rotation can be prevented by means of a not-shown blocking mechanism. The guide element 1 is also longitudinally divided into two sleeve halves 1a, 1b. These two sleeve halves collectively form a through-opening 1c that is adapted to the shape of the profile and has a rounded edge 1d on the inlet side. Referred to the feed direction V of a profile 7 to be bent with a longitudinal axis L, particularly a hollow profile, a shaped element 1e (see Figure 2) that is also realized in a sleeve-shaped fashion and manufactured from an elastic rubber material is arranged downstream of the sleeve halves 1a, 1b. This shaped element is also adapted to the cross-sectional shape of the profile 7 and rigidly connected to the lower sleeve half 1b. In addition, the bending device contains a feed unit 3 that is realized in the form of profile tongs and serves for seizing the profile 7 on its rear end 7a referred to the feed direction V. The feed unit 3 can be displaced in a feed direction V by means of a not-shown linear drive. In addition, the feed unit 3 is provided with a not-shown rotary drive for turning the feed unit 3 and the profile 7 about the longitudinal axis L.

A carrier element 4 in the form of a carrier plate is arranged downstream of the guide element 1 and the shaped element 1e referred to the feed direction V and connected to the stationary receptacle block 2 by means of two parallel rockers 4a (see Figure 3). In this case, the carrier element 4 is rotatably supported in the rockers 4a and the rockers 4a are rotatably supported in the

receptacle block 2. This means that the carrier element 4 and the rockers 4a collectively form a coupling gear. The carrier element 4 contains a round opening 4b, in which an inserted bending sleeve 5 is rotatably supported by means of a bearing 4c (see Figure 4). In addition, the bending sleeve 5 is supported by the carrier element 4 such that it can be eccentrically pivoted about two hinge points P_1 of the rockers 4a that are arranged on an axis extending perpendicular to the longitudinal profile axis L. The rockers 4a are supported such that they can be respectively pivoted about a second hinge point P_2 that is arranged eccentric referred to the longitudinal profile axis L on the same side of the profile. A not-shown rotary drive for turning the bending sleeve is integrated into the carrier element 4. The inside cross section 5a of the bending sleeve 5 is also adapted to the shape of the profile 7 to be bent, particularly square or circular, but larger than the through-opening 1c in the guide element 1. The edges 5b of the through-opening in the bending sleeve 5 are rounded on the inlet side and the outlet side in order to simplify the insertion of the profile. In addition, the inner surface of the bending sleeve 5 contains a linear region 5c referred to the feed direction V (see Figure 4).

A fork-shaped boom 2b with a curved guide groove 2d machined into its respective branches 2c is mounted on the receptacle block 2. The carrier element 4 is displaceably supported in the guide grooves 2d of the boom 2b by means of outwardly directed guide pins 4c. An adjusting arm 4d extending around the extended axis of rotation 6a of a disk-shaped bending table 6 is also rigidly connected to the carrier element 4. The bending table 6 may form part of a conventional drawing/bending device. Two outwardly directed guide pins 4e are also arranged on the end of the

adjusting arm 4d. These guide pins engage into guide grooves 6c machined into two parallel boom arms 6b. The boom arms 6b are rigidly connected to the axis of rotation 6a of the bending table 6 with one end and consequently can be adjusted together with the bending table 6 by means of its not-shown rotary drive.

The bending device according to the invention functions as described below:

The hollow profile 7 to be bent is firmly clamped in the feed unit 3 with its end 7a. A bending block 8 inserted into the hollow profile 7 is guided by the feed unit 3 and fixed downstream thereof by means of a not-shown stationary mounting element. This bending block consists of a flexible front block section 8a, particularly a bead chain for a pipe with circular cross section, and a not-shown rear grip head that axially holds the bending block 8. The bending block 8 serves for preventing the profile 7 from collapsing and from excessively developing wrinkles during the course of the bending process. This is achieved in that its block section 8a adjoins and supports the inside of the hollow profile 7. When processing an angular hollow profile, e.g., a pipe with square cross section, the block section naturally needs to have a corresponding cross-sectional shape.

When preparing for the bending process, the hollow profile 7 is moved into the guide element 1 by the linear drive of the feed unit 3 that takes hold of the hollow profile 7 on its rear end 7a. The rounded edge 1d on the inlet side of the through-opening 1c of the guide element 1 simplifies this insertion process. Due to the correspondingly chosen inner cross-sectional shape of the through-opening 1c, the

guide element 1 adjoins the hollow profile 7 with a positive fit. Before the bending process is initiated, the carrier element 4 is in a starting position I, in which the bending sleeve 5 is aligned with the guide element 1. The hollow profile 7 is now moved through the guide element 1 and the shaped element 1e to such a degree that its opposite end 7b referred to the feed unit 3, at the height of which the block section 8a of the inserted bending block 8 is situated, slightly protrudes over the bending sleeve 5.

When initiating the bending processes in initially one plane (2D bending), the boom arms 6b are turned in the clockwise direction by an angle α together with the bending table 6, namely while the hollow profile 7 is moved with a constant feed rate and the bending block 8 is axially held in position. The carrier element 4 follows this movement under the influence of its adjusting arm 4d, wherein the guide pins 4e travel radially outward in their assigned guide groove 6c. The carrier element 4 is pivoted relative to the feed direction V of the hollow profile 7, wherein said pivoting movement is composed of a rotational movement and a translational movement, at least one component of which extends perpendicular to the profile axis L. Once the pivoting of the boom arms 6b by the angle α is completed, the carrier element 4 is situated in a position II, in which it is turned further in the clockwise direction than in Figures 1 and 2. Analogous to any other possible position, this position is uniquely defined by the respective position of the guide pins 4c, 4e in the guide grooves 2c machined into the boom ends 2b, as well as by the position of the carrier element 4 relative to the rockers 4a. In this context, each position of the carrier element 4 corresponds to a specific bending

radius. Consequently, the desired bending radius can be easily adjusted by choosing the turning angle α accordingly.

When initiating the 3D free-form bending, i.e., a change of the bending direction and a change of the bending plane, the feed movement is stopped and the hollow profile 7 is turned by the desired angle with the aid of the rotary drive connected to the profile collet chuck 3. The guide element 1 that is rotatably supported in the receptacle block 2 and the bending sleeve 5 that is rotatably supported in the carrier element 4 participate in this turning movement. In contrast to the state of the art, the profile 7 to be bent does not have to be strictly rotationally symmetrical in order to be subjected to a 3D free-form bending process on a device according to the invention.

While the hollow profile 7 is turned by the feed unit 3, the already bent section of the hollow profile 7 is turned out of the defined bending plane B of the bending device, and the adjacent hollow profile 7 section that is advanced once the feed movement commences is bent in the bending plane B in a spatially unchanged fashion. During this process, the profile section situated at the height of the bending sleeve 5 when the hollow profile 7 is turned also moves out of the bending plane B. This can be achieved without having to adjust the bending sleeve 5, namely because the through-opening 5a of the bending sleeve 5 includes a certain lateral clearance in addition to the outside dimensions of the profile 7 such that sufficient free space is available for the profile 7.

If a profile with non-circular cross section not only needs to be bent, but also subjected to a superimposed

torsion, the guide element 1 is blocked with the aid of the blocking mechanism, and the bending sleeve 5 is turned in a defined fashion. However, the bending plane cannot be changed in this case.

If it is also necessary to change the bending radius, the position of the carrier element 4 that holds the bending sleeve 5 is also changed in the previously described fashion by turning the boom arms 6b together with the bending table 6.